

**NuTRoNS 1: Nucleonica Training Course on Nuclear Science**  
**Joint EC / IAEA Monaco Nuclear Science Training Course**  
**12 - 15 October 2010, Monaco**

# **Gamma Spectrum Generator: Exercises**

**Andrey BERLIZOV**

*National Academy of Sciences of Ukraine  
Institute for Nuclear Research, Kiev, Ukraine*

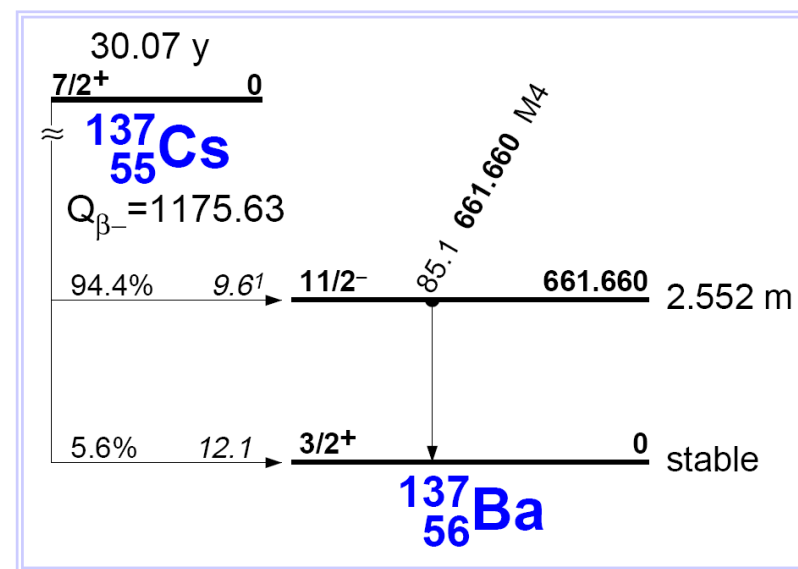
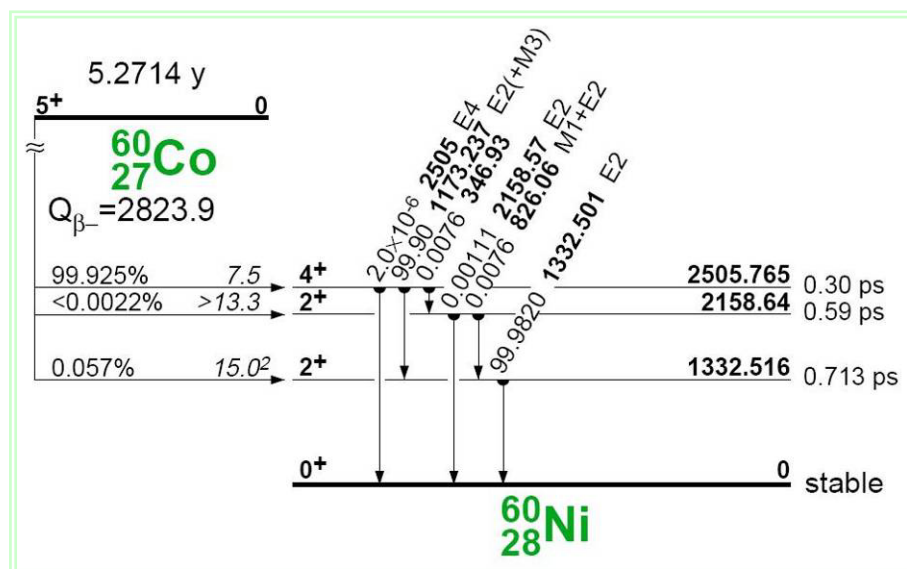
*European Commission, Joint Research Centre  
Institute for Transuranium Elements, Karlsruhe, Germany*

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- **Exercise #1: predicting the number of counts / count rate**
- **Exercise #2: coping with the elevated count rates**
- **Exercise #3: selecting a detector with an appropriate efficiency**
- **Exercise #4: exploring nuclide contribution to a gamma-spectrum**
- **Exercise #5: studying the detectability of a nuclide**

- The measurement setup is similar to the default configuration “NaI,  $L \times D = 1$  in  $\times 2$  in (default)”. You are going to calibrate it using the 1 MBq  $^{60}\text{Co}$  and 1 MBq  $^{137}\text{Cs}$  reference gamma sources. Approximately, how many statistical counts can you expect within 100 s in the corresponding gamma-spectra? Make the evaluations with and without backscattered photon contribution.



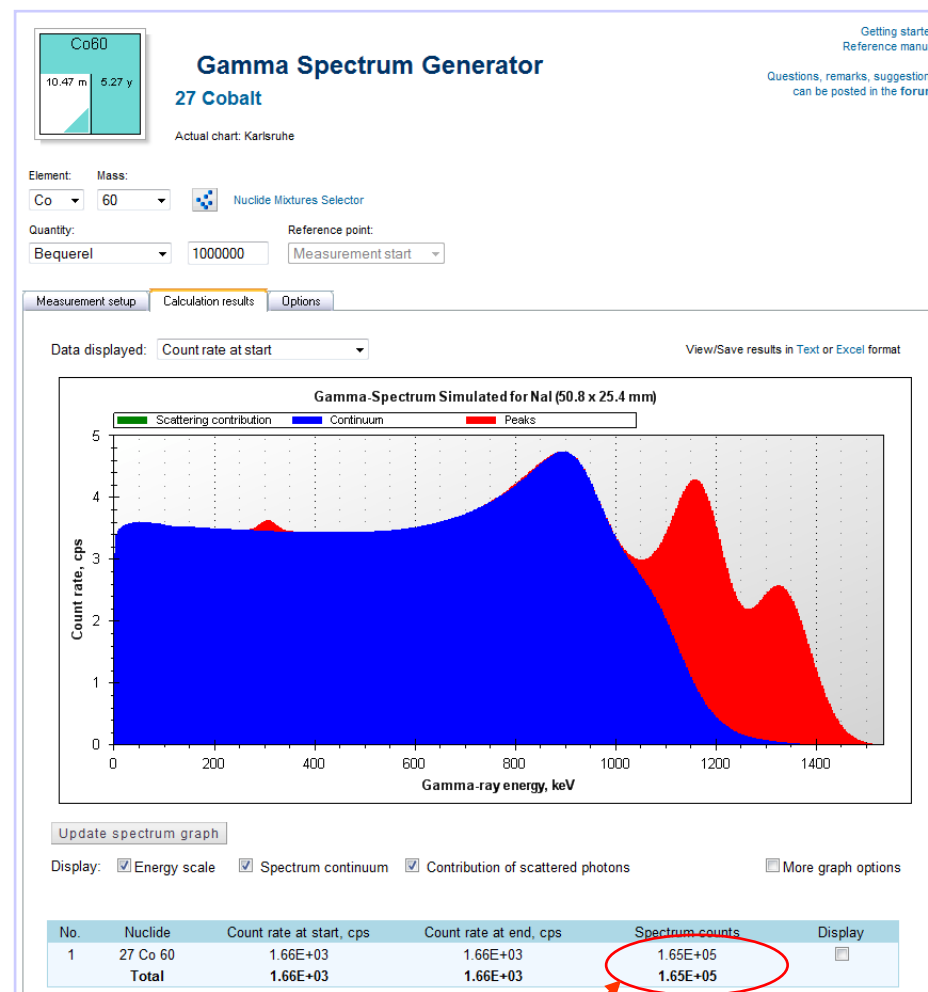
## Select Co-60

## Specify the nuclide's activity

## Specify the measurement time

## Click on "Start" to run a simulation

The screenshot shows the Nucleonica Gamma Spectrum Generator web application. The 'Element' is set to 'Co' and 'Mass' to '60'. The 'Quantity' is set to 'Bequerel' and the value is '1000000'. The 'Reference point' is set to 'Measurement start'. The 'Measurement time' is set to 'sec' and the value is '100'. The 'Start' button is highlighted. The 'Current configuration' is set to 'Nal, L x D = 1 in x 2 in (default)'. A diagram of the detector setup is shown with labels for 'Source', 'Filter', 'Crystal', 'Crystal diameter' (50.8), 'Crystal length' (25.4), and 'Source to Detector distance' (250.0).



## Select a spectrometer configuration

## Here is the answer

Make a note of additional counts due to the backscattered photons forming a so-called “backscatter peak”

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**Gamma Spectrum Generator**  
27 Cobalt

Actual chart: Karlsruhe

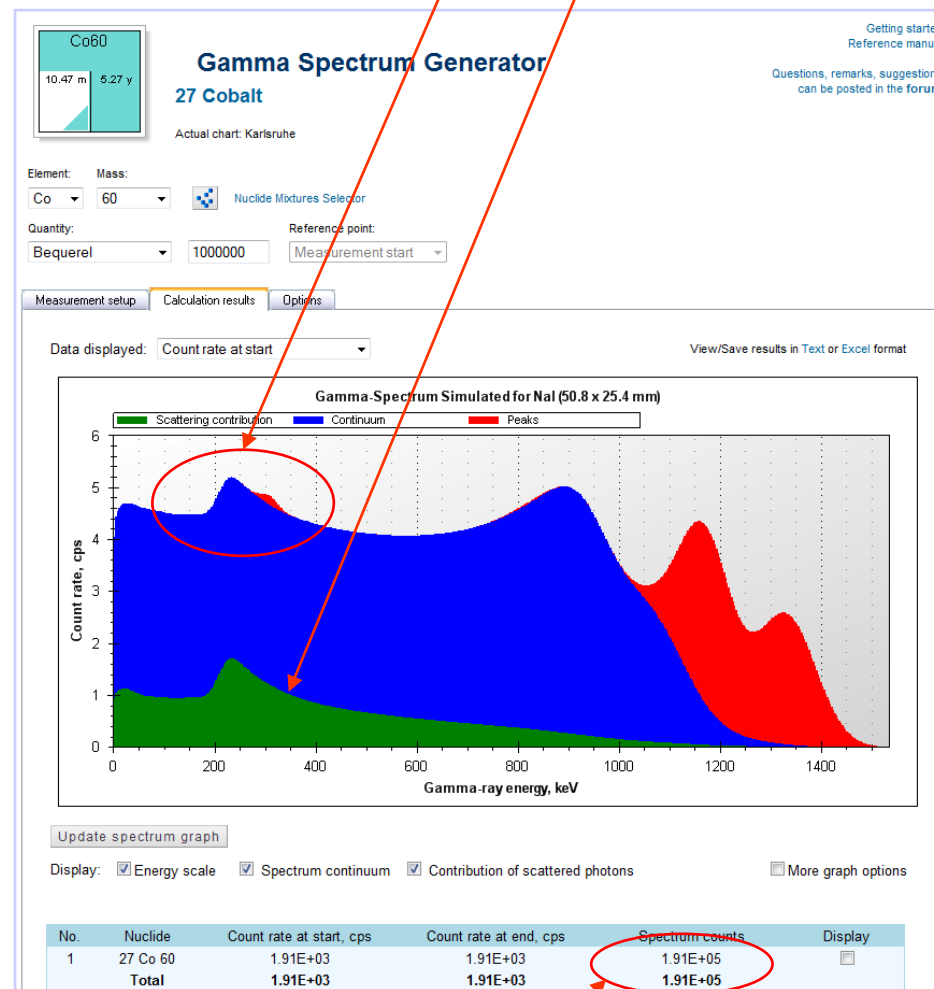
Element: Co Mass: 60  
Quantity: Bequerel 1000000 Reference point: Measurement start

Measurement setup Calculation results Options

Gamma Spectrum Generator Settings:

- ☐ Display detector efficiency curves
- ☐ Consider decay transformations during cooling and counting time intervals
- ☒ Consider effects of backscatter radiation
- 1.0 Backscatter peak normalisation factor

Go to the “Options” tab and enable the modeling of the backscatter photon contribution



Here is the answer

Make sure that  $^{137}\text{Cs}$  is selected

**Gamma Spectrum Generator**  
55 Cesium

Actual chart: Karlsruhe

Element: Cs Mass: 137

Quantity: Bequerel 1000000

Reference point: Nuclide creation

"Cooling" time: min 15

Measurement setup Calculation results Options

**Gamma Spectrum Generator Settings:**

- ☐ Display detector efficiency curves
- ☒ Consider decay transformations during cooling and counting time intervals
- ☒ Include gamma-rays of daughter nuclides
- 0.01 Decay Engine's accuracy factor
- ☐ Consider effects of backscatter radiation

To simulate a typical spectrum for  $^{137}\text{Cs}$ , it is important:

- to enable the decay calculations, and
- to specify the duration of the pre-measurement ("cooling") time interval to allow the accumulation of the daughter isomer  $^{137\text{m}}\text{Ba}$

**Gamma Spectrum Generator**  
55 Cesium

Actual chart: Karlsruhe

Element: Cs Mass: 137

Quantity: Bequerel 1000000

Reference point: Nuclide creation

"Cooling" time: min 15

Measurement setup Calculation results Options

Measurement time: sec 100

Start Start in background

Current configuration: NaI, L x D = 1 in x 2 in (default)

Save as Delete

Dimensions in mm

Source

Filter

NaI Crystal

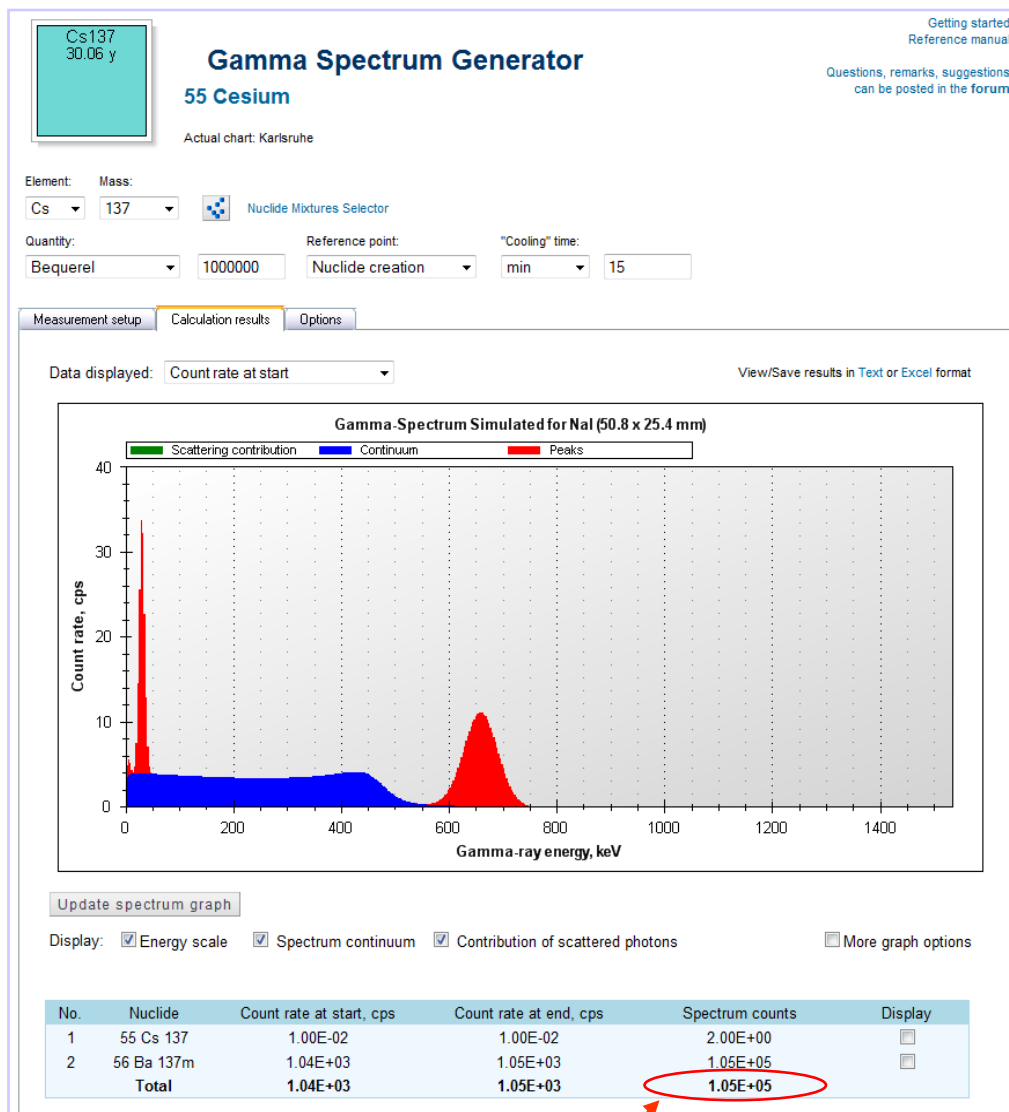
Crystal diameter: 50.8

Source to Detector distance: 250.0

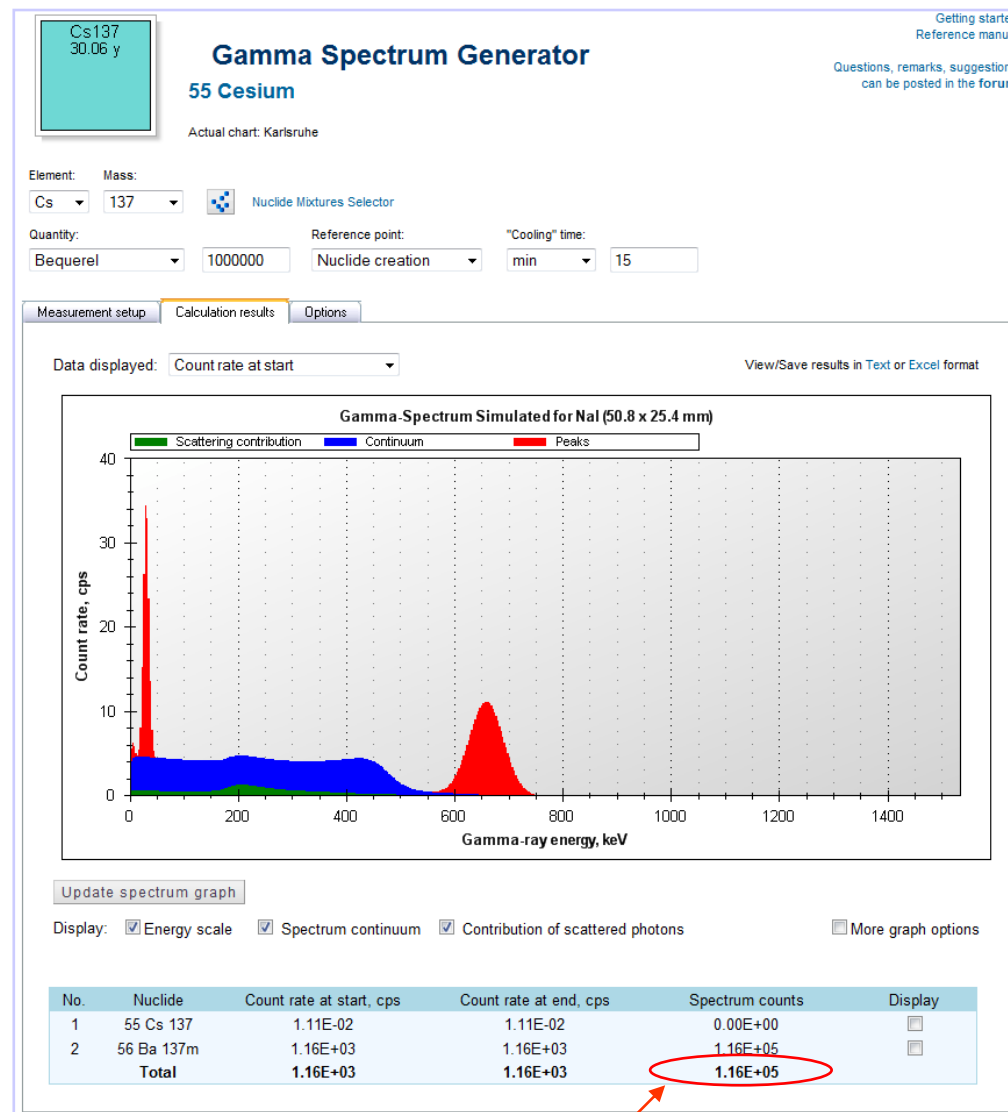
Crystal length: 25.4

Show more settings

Click on "Start"  
to run the simulation



Here is the answer (without the backscatter peak)



Here is the answer (with the backscatter peak)

### Answers:

<sup>60</sup>Co:

- without backscatter photons  $\approx 1.66 \cdot 10^5$  counts
- with backscatter photons  $\approx 1.91 \cdot 10^5$  counts

<sup>137</sup>Cs:

- without backscatter photons  $\approx 1.06 \cdot 10^5$  counts
- with backscatter photons  $\approx 1.18 \cdot 10^5$  counts

2. You have to measure the 10 MBq  $^{152}\text{Eu}$  source with NaI (3"×3") scintillation detector in the measurement setup similar to the default configuration “NaI,  $L \times D = 3 \text{ in} \times 3 \text{ in}$  (default)”. In your disposal there are three lead filters – 1 mm, 3 mm and 5 mm thick.

### Questions:

- Find right combinations of the filters, which would make the measurement possible, assuming that your electronics can cope only with input count rates below 20 kcps (kilo counts per second).
- Check if the same electronics and filters will allow you to perform the measurement in the configuration “HPGe, coaxial, p-type, rel. eff. 150% (default)”.

## Set up the nuclide and measurement geometry settings as requested by the exercise

**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152  
Quantity: Bequerel Reference point: Measurement start

Measurement time: sec 100 Start Start in background

Current configuration: Nal, L x D = 3 in x 3 in (default) Save as Delete

Dimensions in mm

Source to Detector distance: 250.0

Crystal length: 76.2

Crystal diameter: 76.2

Filter

Nal Crystal

Show more settings

**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152  
Quantity: Bequerel Reference point: Measurement start

Measurement time: sec 100 Start Start in background

Current configuration: <..Edit..> Save as Delete

Dimensions in mm

Source to Detector distance: 250.0

Crystal length: 76.2

Crystal diameter: 76.2

Filter

Nal Crystal

Show more settings

Filter: Lead 1.0 Add filter layer Remove filter layer

Input window: Aluminum 0.5

Crystal packaging: Foam Plastic 0.0

Inactive layer / Reflector: Magnesium oxide 0.5

Number of channels in the spectrum accumulated: 2048

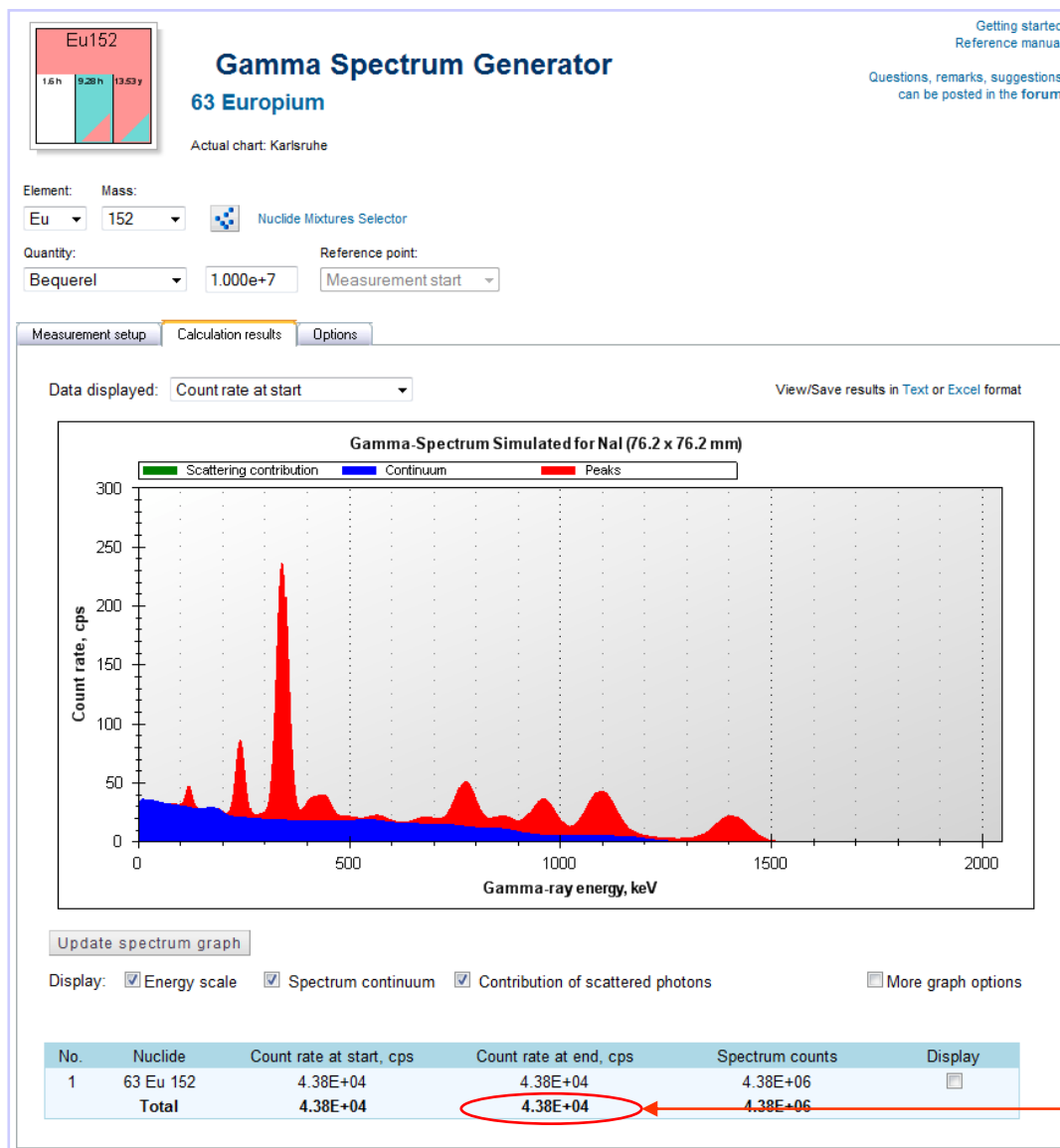
Channel-to-energy conversion factor, keV/channel: 1.0

Energy resolution (FWHM) in keV at 122 keV: 18.0

Energy resolution (FWHM) in keV at 1332 keV: 90.0

No.	Layer material	Thickness
1	Lead	1.0

Add / Remove filters using “Add filter layer” and “Remove filter layer” buttons



Do similar calculations:

- for all filter combinations to see which combinations are appropriate,
- for the default 150% HPGe spectrometer configuration to see if the electronics is suitable.

Here is the value to be compared with the count rate limit of 20 kcps

### Answers:

#### Valid filter combinations:

- 8 mm = 3 mm + 5 mm (18.8 kcps),
- 9 mm = 1 mm + 3 mm + 5 mm (17.2 kcps).

The electronics is **not suitable** for the configuration with 150% HPGe detector since even for the thickest filter combination the predicted input count rate is 22.6 kcps.

3. You have an HPGe detector with crystal length – 30 mm, crystal diameter – 50 mm, rear contact length – 20 mm, rear contact diameter – 10 mm, inactive Ge – 1.5 mm, cap thickness – 1 mm Al, and crystal to cap distance – 5 mm.

### Questions:

- What is the relative efficiency of your detector?
- What crystal length would double the relative efficiency?

# Exercise #3: selecting an appropriate detector

**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152  
Quantity: Bequerel Reference point: Measurement start

Measurement setup Calculation results Options

Measurement time: sec 100 Start Start in background

Current configuration: <..Edit..> Save as Delete

Dimensions in mm

Source to Detector distance: 250.0

Filter

HPGe Crystal

Crystal diameter: 50

Contact diameter: 10.0

Contact length: 20

Crystal length: 30

Show more settings

Filter: Lead 1.0

Input window: Aluminum 1

Crystal packaging: Vacuum 5

Inactive layer / Reflector: Germanium 1.5

Number of channels in the spectrum accumulated: 8192

Channel-to-energy conversion factor, keV/channel: 0.3

Energy resolution (FWHM) in keV at 122 keV: 1.3

Energy resolution (FWHM) in keV at 1332 keV: 2.3

**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152  
Quantity: Bequerel Reference point: Measurement start

Measurement setup Calculation results Options

Data displayed: Count rate at start View/Save results in Text or Excel format

Gamma-Spectrum Simulated for HPGe (rel. eff. 10.5%)

Count rate, cps

Gamma-ray energy, keV

Scattering contribution Continuum Peaks

Update spectrum graph

Display: ☒ Energy scale ☒ Spectrum continuum ☒ Contribution of scattered photons ☐ More graph options

No.	Nuclide	Count rate at start, cps	Count rate at end, cps	Spectrum counts	Display
1	63 Eu 152	2.14E+04	2.14E+04	2.15E+06	<input type="checkbox"/>
	Total	2.14E+04	2.14E+04	2.15E+06	

**Answer #1:**  
Relative efficiency = 10.5%

# Exercise #3: selecting an appropriate detector

**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152  
Quantity: Bequerel 1.000e+7  
Reference point: Measurement start

Measurement setup Calculation results Options

Measurement time: sec 100 Start Start in background

Current configuration: <...Edit...> Save as Delete

Dimensions in mm

Source to Detector distance: 250.0

Filter

HPGe Crystal

Crystal diameter: 50

Contact diameter: 10.0

Contact length: 20

Crystal length: 46.5

Show more settings

Filter: Aluminum 1.0 Add filter layer Remove filter layer

Input window: Aluminum 1

Crystal packaging: Vacuum 5

Inactive layer / Reflector: Germanium 1.5

Number of channels in the spectrum accumulated: 8192

Channel-to-energy conversion factor, keV/channel: 0.3

Energy resolution (FWHM) in keV at 122 keV: 1.3

Energy resolution (FWHM) in keV at 1332 keV: 2.3

**Answer #2:**  
crystal length L = 46.5 mm

**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152  
Quantity: Bequerel 1.000e+7  
Reference point: Measurement start

Measurement setup Calculation results Options

Data displayed: Count rate at start View/Save results in Text or Excel format

Gamma-Spectrum Simulated for HPGe (rel. eff. 21.0%)

Count rate, cps

Channel number

Update spectrum graph

Display: ☐ Energy scale ☐ Spectrum continuum ☐ Contribution of scattered photons ☐ More graph options

No.	Nuclide	Count rate at start, cps	Count rate at end, cps	Spectrum counts	Display
1	63 Eu 152	2.48E+04	2.48E+04	2.48E+06	<input type="checkbox"/>
	<b>Total</b>	<b>2.48E+04</b>	<b>2.48E+04</b>	<b>2.48E+06</b>	

**Relative efficiency = 21.0%**

4. The 1 g natural uranium sample ( $^{234}\text{U}$  – 0.000055 g,  $^{235}\text{U}$  – 0.0072 g,  $^{238}\text{U}$  – 0.992745 g) was measured twice using the same NaI (3"×3") scintillation spectrometer (configuration “NaI, L × D = 3 in × 3 in (default)”). The first and second measurements were performed for 100000 s, 10 days and 1 year after the uranium separation, respectively.

### Question:

- What are the relative contributions of  $^{235}\text{U}$  and  $^{238}\text{U}$  to the gamma-spectrum measured in both measurements?

### Suggestion:

- When modeling gamma-spectra, use the 1 mm Pb filter to imitate the self-attenuation of gamma-rays by the uranium sample.

Click on “Nuclide Mixtures Selector”

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**Gamma Spectrum Generator**  
63 Europium

Actual chart: Karlsruhe

Element: Eu Mass: 152

Quantity: Bequerel Reference point: Measurement start

**Nuclide Mixtures Selector**

Measurement setup Calculation results Options

Measurement time: sec 100000 Start Start in background

Current configuration: NaI, L x D = 3 in x 3 in (default) Save as Delete

Dimensions in mm

Source Filter Crystal

Crystal diameter 76.2

Source to Detector distance 250.0 Crystal length 76.2

Show more settings

Select a pre-defined mixture “NatU 1 g”

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**Gamma Spectrum Generator**  
NatU 1 g

Actual chart: Karlsruhe

Nuclide mixtures: NatU 1 g Nuclide Selector

Total activity: Bequerel Reference point: Measurement start

Measurement setup Calculation results Options

Measurement time: sec 100000 Start Start in background

Current configuration: NaI, L x D = 3 in x 3 in (default) Save as Delete

Dimensions in mm

Source Filter Crystal

Crystal diameter 76.2

Source to Detector distance 250.0 Crystal length 76.2

Show more settings

# Exercise #4: exploring nuclide contributions

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**Gamma Spectrum Generator**  
NatU 1 g  
Actual chart: Karlsruhe

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Nuclide Mixtures:  
NatU 1 g Nuclide Selector

Total activity:  
Bequerel 2.557e+004

Reference point:  
Mixture creation

"Cooling" time:  
day 10

Measurement setup Calculation results Options

Gamma Spectrum Generator Settings:

- ☐ Display detector efficiency curves
- ☒ Consider decay transformations during cooling and counting time intervals
- ☒ Include gamma-rays of daughter nuclides
- 0.01 Decay Engine's accuracy factor
- ☐ Consider effects of backscatter radiation

Specify the time elapsed since the uranium separation

Enable decay transformations on the "Options" tab

Add a 1 mm Pb filter to imitate the self-attenuation of gamma-rays by the sample

**Gamma Spectrum Generator**  
NatU 1 g  
Actual chart: Karlsruhe

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Nuclide Mixtures:  
NatU 1 g Nuclide Selector

Total activity:  
Bequerel 2.557e+004

Reference point:  
Mixture creation

"Cooling" time:  
day 10

Measurement setup Calculation results Options

Measurement time: sec 100000 Start Start in background

Current configuration: <..Edit.> Save as Delete

Dimensions in mm

Source

Filter

Crystal

Crystal diameter: 76.2

Crystal length: 76.2

Source to Detector distance: 250.0

Filter: Lead 1.0

Input window: Aluminum 0.5

Crystal packaging: Foam Plastic 0.0

Inactive layer / Reflector: Magnesium oxide 0.5

Number of channels in the spectrum accumulated: 2048

Channel-to-energy conversion factor, keV/channel: 1.0

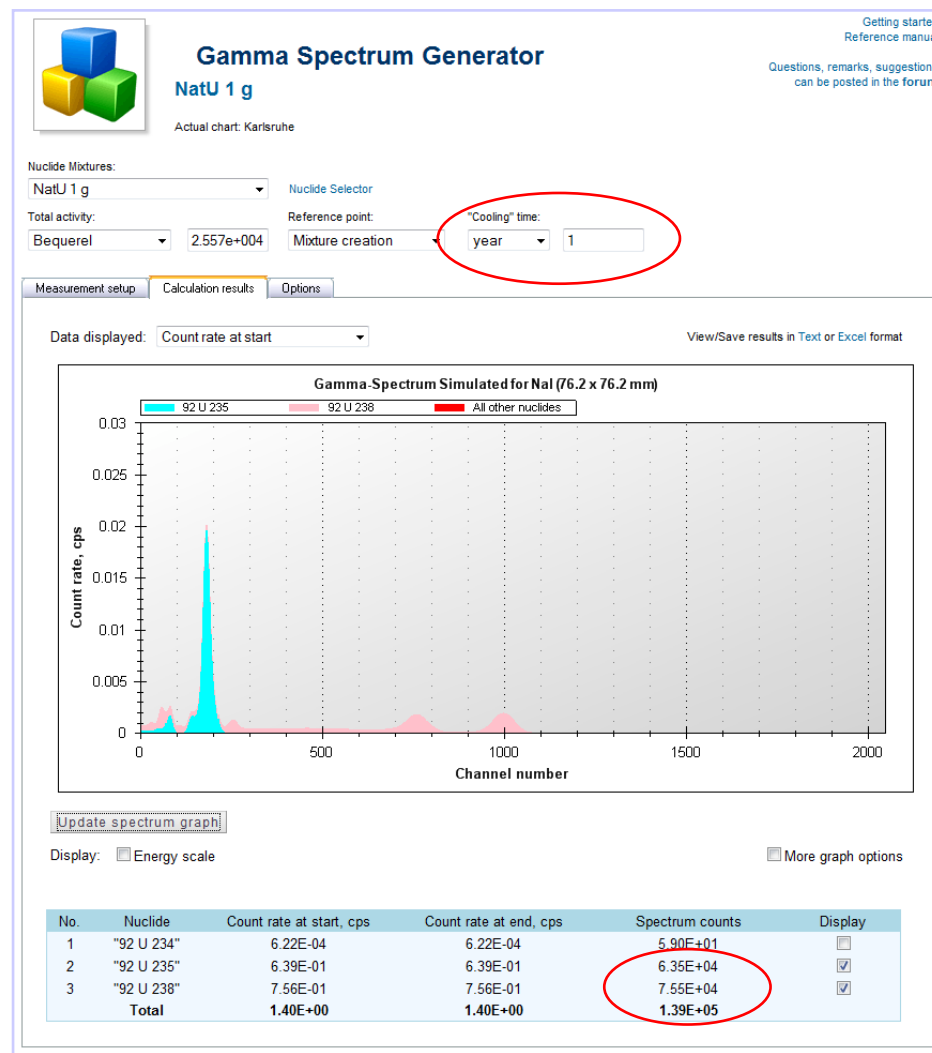
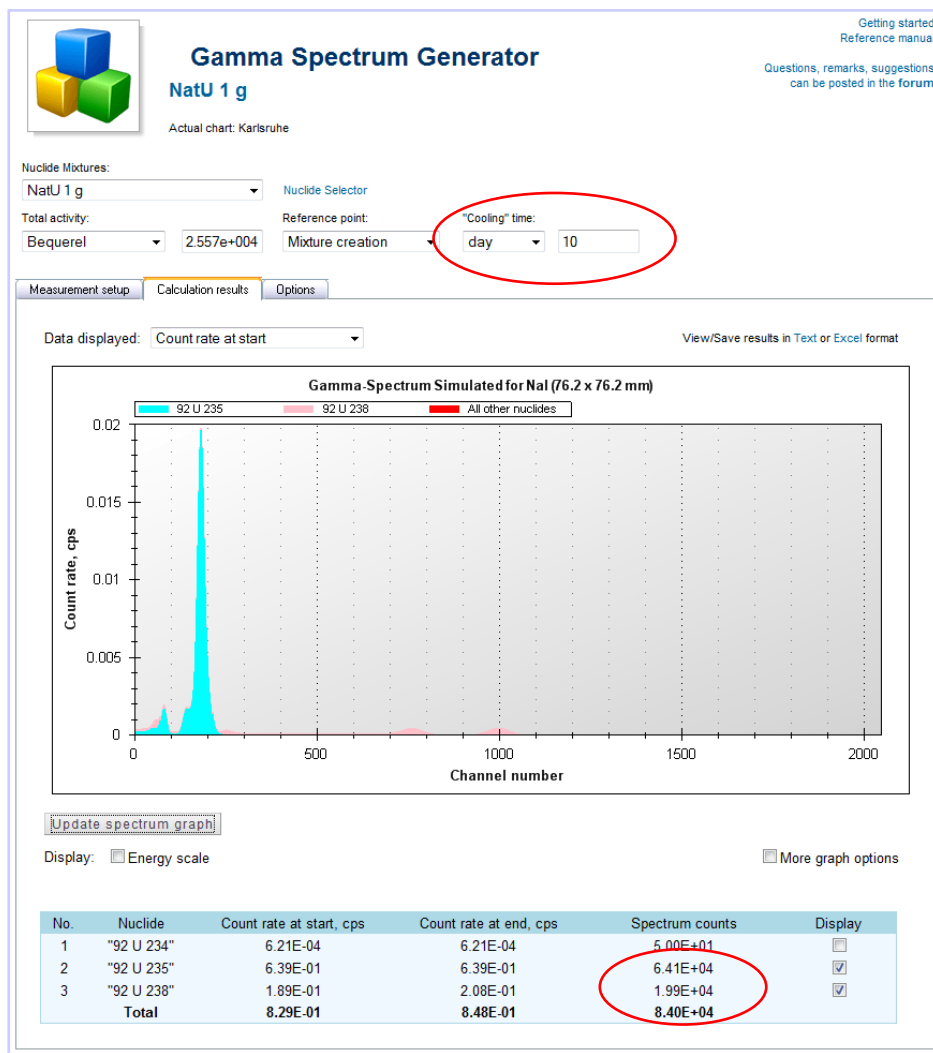
Energy resolution (FWHM) in keV at 122 keV: 18.0

Energy resolution (FWHM) in keV at 1332 keV: 90.0

Add filter layer Remove filter layer

No.	Layer material	Thickness
1	Lead	1.0

# Exercise #4: exploring nuclide contributions



Answers: after 10 days  $^{235}\text{U}$  - 76% and  $^{238}\text{U}$  - 24%; after 1 year  $^{235}\text{U}$  - 46% and  $^{238}\text{U}$  - 54%.

**5. Based on the gamma-spectrometric examination of a source, the presence of  $^{60}\text{Co}$  with activity of 100 kBq was revealed.**

**Question:**

- **Which of the default GSG measurement configurations are suitable for detecting an additional presence of 50 Bq of  $^{241}\text{Am}$  in the same source by performing a 1000 s long measurement?**

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Version: 2010.10.01 14:40:39

## Nuclide Mixtures

Getting started  
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My Mixtures Edit Upload Sample Mixtures

Name  
Co-60 10 kBq + Am-241 50 Bq

Description  
GSG Problem No.5

Nuclide	Activity(Bq)	Mass(g)	Number of Atoms	Mass ratio	Mole ratio	Activity ratio	Delete
95 Am 241	50.00	3.944e-10	9.852e+11	0.1417	0.03944	4.998e-4	
27 Co 60	1.000e+5	2.388e-9	2.400e+13	0.8583	0.9606	0.9995	
<b>Total: 2</b>	<b>1.001e+5</b>	<b>2.783e-9</b>	<b>2.498e+13</b>	<b>1</b>	<b>1</b>	<b>1</b>	

Significant figures: 4

Element Mass Quantity Unit

Update

Save Mixture Reset Cancel

Go to “Nuclide Mixtures” and create a new mixture consisting of 10 kBq  $^{60}\text{Co}$  and some amount of  $^{241}\text{Am}$

In the GSG select the mixture

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## Gamma Spectrum Generator

Co-60 10 kBq + Am-241 50 Bq

Actual chart: Karlsruhe

Nuclide Mixtures: Co-60 10 kBq + Am-241 50 Bq Nuclide Selector

Total activity: Bequerel 1.000e+005 Reference point: Measurement start

Measurement setup Calculation results Options

Measurement time: sec 1000 Start Start in background

Current configuration: Nal, L x D = 3 in x 3 in (default) Save as Delete

Dimensions in mm

Source

Filter

NaI Crystal

Crystal diameter 76.2

Crystal length 76.2

Source to Detector distance 250.0

Show more settings

Select a default configuration to be tested

**Gamma Spectrum Generator**  
Co-60 10 kBq + Am-241 50 Bq

Actual chart: Karlsruhe

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Nuclide Mixtures:  
Co-60 10 kBq + Am-241 50 Bq

Total activity:  
Bequerel

Reference point:  
1.000e+005

Measurement start

Measurement setup Calculation results Options

Data displayed: Count rate at start

View/Save results in Text or Excel format

Gamma-Spectrum Simulated for NaI (76.2 x 76.2 mm)

Count rate, cps

Channel number

Update spectrum graph

Display: ☐ Energy scale ☐ Spectrum continuum ☐ Contribution of scattered photons ☐ More graph options

No.	Nuclide	Count rate at start, cps	Count rate at end, cps	Spectrum counts	Display
1	"27 Co 60"	6.92E+02	6.92E+02	6.93E+05	<input type="checkbox"/>
2	"95 Am 241"	1.21E-01	1.21E-01	1.19E+02	<input type="checkbox"/>
	Total	6.92E+02	6.92E+02	6.93E+05	

Click "Text" to download calculation results

**Gamma Spectrum Generator**  
Co-60 10 kBq + Am-241 50 Bq

Actual chart: Karlsruhe

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can be posted in the forum

Nuclide Mixtures:  
Co-60 10 kBq + Am-241 50 Bq

Total activity:  
Bequerel

Reference point:  
1.000e+005

Measurement start

Measurement setup Calculation results Options

Data displayed: Count rate

View/Save results in Text or Excel format

Gamma-Spectrum Simulated for NaI (76.2 x 76.2 mm)

Count rate, cps

Channel number

Update spectrum graph

Display: ☐ Energy scale ☐ Spectrum continuum ☐ Contribution of scattered photons ☐ More graph options

No.	Nuclide	Count rate at start, cps	Count rate at end, cps	Spectrum counts	Display
1	"27 Co 60"	6.92E+02	6.92E+02	6.93E+05	<input type="checkbox"/>
2	"95 Am 241"	1.21E-01	1.21E-01	1.19E+02	<input type="checkbox"/>
	Total	6.92E+02	6.92E+02	6.93E+05	

Select "Open with Editor" and press OK

Öffnen von customer\_174\_1.txt

Sie möchten folgende Datei herunterladen:

customer\_174\_1.txt

Vom Typ: Text Document

Von: http://www.nucleonica.net

Wie soll Firefox mit dieser Datei verfahren?

☒ Öffnen mit Editor (Standard)

☐ Datei speichern

☐ Für Dateien dieses Typs immer diese Aktion ausführen

OK Abbrechen

# Exercise #5: studying the detectability of a nuclide

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Datei Bearbeiten Format Ansicht ?

Nucleonica - GAMMA SPECTRUM GENERATOR Version 1.0.0.1

Content: Calculation Results  
Created: 08.10.2010 23:00:43 (UTC)

INPUT PARAMETERS::

SPECTROMETER:  
Configuration name - NaI, L x D = 3 in x 3 in  
Crystal (Length x Diameter) - NaI (76.2 mm x 76.2 mm)  
Inactive layer - 0.5 mm Magnesium oxide  
Crystal packaging - 0 mm Foam Plastic  
Detector input window - 0.5 mm Aluminum  
Number of additional filters - 0  
FWHM at 122 keV - 18 keV  
FWHM at 1332.5 keV - 90 keV  
Number of channels - 2048  
Channel-to-Energy conversion - 1 keV/channel  
Source-to-Detector distance - 250 mm  
Spectrum measurement time - 1.000E+003 sec

SOURCE:  
Nuclide mixture - Co-60 10 kBq + Am-241 50 Bq  
Total activity - 1.000E+005 Becquerel  
Reference point of time - Measurement start

CALCULATION:  
Consider decay transformations - No  
Consider backscatter radiation - No

CALCULATION RESULTS::

NUCLIDES:

Nuclide	Ancestor	Activity, Bq	at start	at end	Numb of dec
"27 Co 60"	27 Co 60	9.995E+004	9.995E+004	9.995E+004	9.995E+004
"95 Am 241"	95 Am 241	4.998E+001	4.998E+001	4.998E+001	4.998E+001
TOTAL:		1.000E+005	1.000E+005	1.000E+005	1.000E+005

X-RAYS AND GAMMA-RAYS:

Ancestor	Emitter	Energy, keV	X/G ray	Photons per decay
27 Co 60	27 Co 60	0.850	X	1.495E-006
27 Co 60	27 Co 60	7.461	X	3.270E-005

Scroll down the text to display the "X-rays and Gamma-rays" table

Find an <sup>241</sup>Am gamma-line with the lowest MDA value

customer\_174\_1 - Editor

Datei Bearbeiten Format Ansicht ?

X-RAYS AND GAMMA-RAYS:

Ancestor	Emitter	Energy, keV	X/G ray	Photons per decay	Emission rate, 1/s at start	Emission rate, 1/s at end	Photons emitted	Peak region counts peak area	peak bkgr	Detection efficiency total	efficiency FEP	Filter att. factor	Ancestor's MDA(0), Bq
27 Co 60	27 Co 60	0.850	X	1.495E-006	1.494E-001	1.494E-001	1.494E+002	0.000E+000	5.080E+003	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	7.461	X	3.270E-005	3.269E+000	3.269E+000	3.269E+003	0.000E+000	7.642E+003	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	7.478	X	6.438E-005	6.435E+000	6.435E+000	6.435E+003	0.000E+000	7.642E+003	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	8.260	X	1.311E-005	1.310E+000	1.310E+000	1.310E+003	0.000E+000	8.010E+003	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	347.140	G	7.500E-005	7.496E+000	7.496E+000	7.496E+003	2.766E+001	3.088E+004	4.708E-003	3.696E-003	1.000E+000	3.100E+007
27 Co 60	27 Co 60	826.100	G	7.600E-005	7.596E+000	7.596E+000	7.596E+003	1.362E+001	7.321E+004	3.860E-003	1.797E-003	1.000E+000	3.029E+008
27 Co 60	27 Co 60	1173.230	G	9.985E-001	9.980E+004	9.980E+004	9.980E+007	1.321E+005	3.222E+004	3.528E-003	1.327E-003	1.000E+000	4.323E+000
27 Co 60	27 Co 60	1332.490	G	9.998E-001	9.993E+004	9.993E+004	9.993E+007	1.184E+005	1.660E+004	3.413E-003	1.187E-003	1.000E+000	4.153E+000
27 Co 60	27 Co 60	2158.570	G	1.200E-005	1.199E+000	1.199E+000	1.199E+003	2.577E-002	3.678E-002	3.056E-003	7.591E-004	1.000E+000	5.743E+007
27 Co 60	27 Co 60	2505.690	G	2.000E-008	1.999E-003	1.999E-003	1.999E+000	0.000E+000	0.000E+000	2.976E-003	6.559E-004	1.000E+000	NAN
95 Am 241	95 Am 241	4.608	X	6.987E-002	3.492E+000	3.492E+000	3.492E+003	0.000E+000	6.542E+003	0.000E+000	0.000E+000	1.000E+000	NAN
95 Am 241	95 Am 241	14.440	X	3.307E-001	1.653E+001	1.653E+001	1.653E+004	1.764E+001	1.057E+004	1.072E-003	1.072E-003	1.000E+000	1.641E+003
95 Am 241	95 Am 241	97.080	X	1.286E-005	6.428E-004	6.428E-004	6.428E-001	3.178E+003	1.697E+004	5.388E-003	4.956E-003	1.000E+000	1.129E+007
95 Am 241	95 Am 241	101.070	X	2.068E-005	1.033E-003	1.033E-003	1.033E-003	5.132E-003	1.732E+004	5.385E-003	4.978E-003	1.000E+000	1.129E+007
95 Am 241	95 Am 241	113.310	X	2.399E-006	1.199E-004	1.199E-004	1.199E-004	6.000E-004	1.765E+004	5.370E-003	5.010E-003	1.000E+000	1.958E+008
95 Am 241	95 Am 241	114.240	X	4.570E-006	2.284E-004	2.284E-004	2.284E-004	1.100E-004	1.765E+004	5.370E-003	5.010E-003	1.000E+000	51E+007
95 Am 241	95 Am 241	117.500	X	2.564E-006	1.281E-004	1.281E-004	1.281E-004	6.400E-005	1.765E+004	5.370E-003	5.010E-003	1.000E+000	97E+008
95 Am 241	95 Am 241	13.810	G	1.656E-008	8.276E-007	8.276E-007	8.276E-007	4.141E-006	1.327E+004	4.713E-003	4.713E-003	1.000E+000	64E+016
95 Am 241	95 Am 241	26.345	G	2.430E-002	1.214E+000	1.214E+000	1.214E+003	2.620E-001	1.366E+004	4.841E-003	4.311E-003	1.000E+000	93E+003
95 Am 241	95 Am 241	27.040	G	6.264E-003	3.130E-001	3.130E-001	3.130E-001	1.411E-006	1.327E+004	4.713E-003	4.713E-003	1.000E+000	83E+004
95 Am 241	95 Am 241	28.510	G	2.772E-005	1.385E-003	1.385E-003	1.385E-003	1.411E-006	1.327E+004	4.713E-003	4.713E-003	1.000E+000	13E+008
95 Am 241	95 Am 241	31.400	C	6.120E-009	3.058E-007	3.058E-007	3.058E-004	1.411E-006	1.327E+004	4.713E-003	4.713E-003	1.000E+000	6.563E+015
95 Am 241	95 Am 241	33.196	G	1.217E-003	6.081E-002	6.081E-002	6.081E+001	2.620E-001	1.366E+004	4.841E-003	4.311E-003	1.000E+000	3.308E+005
95 Am 241	95 Am 241	38.570	G	1.260E-008	6.297E-007	6.297E-007	6.297E-004	2.459E-006	1.409E+004	5.058E-003	3.907E-003	1.000E+000	3.252E+015
95 Am 241	95 Am 241	40.500	G	6.120E-009	3.058E-007	3.058E-007	3.058E-004	1.217E-006	1.411E+004	5.114E-003	3.979E-003	1.000E+000	1.535E+016
95 Am 241	95 Am 241	42.720	G	3.852E-004	1.925E-002	1.925E-002	1.925E+001	7.755E-002	1.413E+004	5.163E-003	4.030E-003	1.000E+000	4.732E+006
95 Am 241	95 Am 241	43.420	G	6.588E-004	3.292E-002	3.292E-002	3.292E+001	1.331E-001	1.414E+004	5.178E-003	4.046E-003	1.000E+000	1.792E+006
95 Am 241	95 Am 241	51.010	G	5.400E-006	2.699E-004	2.699E-004	2.699E-001	1.152E-003	1.455E+004	5.285E-003	4.273E-003	1.000E+000	2.496E+010
95 Am 241	95 Am 241	54.080	G	2.664E-006	1.331E-004	1.331E-004	1.331E-001	5.794E-004	1.456E+004	5.310E-003	4.356E-003	1.000E+000	9.725E+010
95 Am 241	95 Am 241	55.550	G	1.836E-004	9.175E-003	9.175E-003	9.175E+000	4.029E-002	1.493E+004	5.322E-003	4.394E-003	1.000E+000	2.086E+007
95 Am 241	95 Am 241	56.880	G	2.340E-008	1.169E-006	1.169E-006	1.169E-003	5.173E-006	1.493E+004	5.331E-003	4.426E-003	1.000E+000	1.206E+015
95 Am 241	95 Am 241	59.541	G	3.600E-001	1.799E+001	1.799E+001	1.799E+004	8.063E+001	1.485E+004	5.344E-003	4.485E-003	1.000E+000	4.212E+002
95 Am 241	95 Am 241	64.820	G	5.760E-006	2.879E-004	2.879E-004	2.879E-001	1.321E-003	1.530E+004	5.365E-003	4.592E-003	1.000E+000	1.794E+010
95 Am 241	95 Am 241	67.450	G	2.160E-006	1.079E-004	1.079E-004	1.079E-001	5.004E-004	1.566E+004	5.372E-003	4.638E-003	1.000E+000	1.237E+011
95 Am 241	95 Am 241	69.760	G	2.880E-005	1.439E-003	1.439E-003	1.439E+000	6.729E-003	1.566E+004	5.378E-003	4.678E-003	1.000E+000	6.773E+008
95 Am 241	95 Am 241	75.920	G	5.760E-006	2.879E-004	2.879E-004	2.879E-001	1.370E-003	1.600E+004	5.387E-003	4.764E-003	1.000E+000	1.367E+010
95 Am 241	95 Am 241	78.100	G	2.088E-008	1.043E-006	1.043E-006	1.043E-003	4.996E-006	1.599E+004	5.390E-003	4.792E-003	1.000E+000	9.016E+014
95 Am 241	95 Am 241	92.200	G	6.120E-007	3.058E-005	3.058E-005	3.058E-002	1.505E-004	1.662E+004	5.391E-003	4.926E-003	1.000E+000	8.400E+010
95 Am 241	95 Am 241	96.800	G	1.368E-006	6.837E-005	6.837E-005	6.837E-002	3.394E-004	1.697E+004	5.388E-003	4.954E-003	1.000E+000	4.128E+009
95 Am 241	95 Am 241	98.970	G	2.232E-004	1.115E-002	1.115E-002	1.115E+001	5.537E-002	1.733E+004	5.387E-003	4.968E-003	1.000E+000	7.260E+005
95 Am 241	95 Am 241	102.960	G	2.088E-004	1.043E-002	1.043E-002	1.043E+001	5.197E-002	1.732E+004	5.383E-003	4.985E-003	1.000E+000	7.236E+005
95 Am 241	95 Am 241	109.700	G	1.224E-007	6.117E-006	6.117E-006	6.117E-003	3.061E-005	1.766E+004	5.375E-003	5.008E-003	1.000E+000	5.442E+010
95 Am 241	95 Am 241	115.500	G	8.280E-008	4.138E-006	4.138E-006	4.138E-003	2.076E-005	1.764E+004	5.366E-003	5.021E-003	1.000E+000	1.108E+011
95 Am 241	95 Am 241	120.400	G	4.680E-008	2.339E-006	2.339E-006	2.339E-003	1.175E-005	1.836E+004	5.357E-003	5.027E-003	1.000E+000	3.048E+011
95 Am 241	95 Am 241	123.000	G	1.080E-005	5.397E-004	5.397E-004	5.397E-001	2.713E-003	1.872E+004	5.353E-003	5.030E-003	1.000E+000	1.903E+007
95 Am 241	95 Am 241	125.310	G	4.104E-005	2.051E-003	2.051E-003	2.051E+000	1.031E-002	1.835E+004	5.349E-003	5.033E-003	1.000E+000	3.911E+006
95 Am 241	95 Am 241	129.000	G	7.200E-009	3.598E-007	3.598E-007	3.598E-004	1.809E-006	1.871E+004	5.341E-003	5.031E-003	1.000E+000	7.304E+012
95 Am 241	95 Am 241	135.300	G	2.736E-006	1.367E-004	1.367E-004	1.367E-001	6.867E-004	1.906E+004	5.328E-003	5.027E-003	1.000E+000	8.213E+007

Zeile 83, Spalte 1

Select next default configuration for testing and click on “Start”

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**Gamma Spectrum Generator**  
Co-60 10 kBq + Am-241 50 Bq

Actual chart: Karlsruhe

Getting started  
Reference manual

Questions, remarks, suggestions  
can be posted in the forum

Nuclide Mixtures:  
Co-60 10 kBq + Am-241 50 Bq Nuclide Selector

Total activity:  
Bequerel 1.000e+005 Reference point:  
Measurement start

Measurement setup Calculation results Options

Measurement time: sec 1000 Start Start in background

Current configuration: BEGe, 30 mm x 50 cm2, rel. eff. 30% (default) Save as Delete

Dimensions in mm

Source

Filter

HPGe Crystal

Crystal diameter 79.8

Contact diameter 0.0

Contact length 0.0

Source to Detector distance 50.0

Crystal length 30.0

Show more settings

**Gamma Spectrum Generator**  
Co-60 10 kBq + Am-241 50 Bq

Actual chart: Karlsruhe

Getting started  
Reference manual

Questions, remarks, suggestions  
can be posted in the forum

Nuclide Mixtures:  
Co-60 10 kBq + Am-241 50 Bq Nuclide Selector

Total activity:  
Bequerel 1.000e+005 Reference point:  
Measurement start

Measurement setup Calculation results Options

Data displayed: Statistical number of counts View/Save results in Text or Excel format

**Gamma-Spectrum Simulated for HPGe (rel. eff. 30.6%)**

27 Co 60 95 Am 241

Number of counts

Gamma-ray energy, keV


Update spectrum graph

Display: ☒ Energy scale More graph options

No.	Nuclide	Count rate at start, cps	Count rate at end, cps	Spectrum counts	Display
1	"27 Co 60"	8.57E+03	8.57E+03	8.57E+06	<input checked="" type="checkbox"/>
2	"95 Am 241"	3.41E+00	3.41E+00	3.35E+03	<input checked="" type="checkbox"/>
	<b>Total</b>	<b>8.57E+03</b>	<b>8.57E+03</b>	<b>8.57E+06</b>	

Again click “Text” to  
download results

# Exercise #5: studying the detectability of a nuclide



## Gamma Spectrum Generator

Co-60 10 kBq + Am-241 50 Bq

Actual chart: Karlsruhe

Getting started  
Reference manual

Questions, remarks, suggestions  
can be posted in the forum

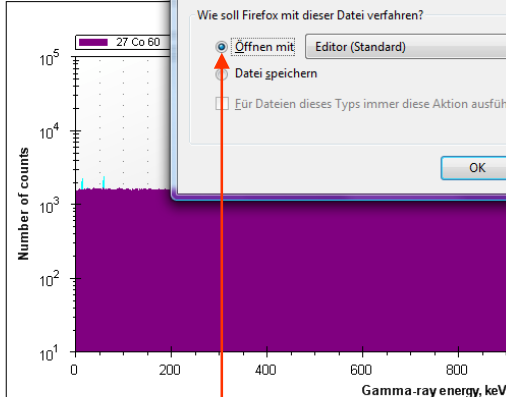
Nuclide Mixtures:  
Co-60 10 kBq + Am-241 50 Bq

Total activity:  
Bequerel

Reference point:  
1.000e

Measurement setup  
Calculation re

Data displayed: Statistical



Update spectrum graph

Display: ☒ Energy scale

No.	Nuclide	Count rate at start, cps	Count rate at end, cps
1	"27 Co 60"	8.47E+03	8.57E+03
2	"95 Am 241"	3.41E+00	3.41E+00
	<b>Total</b>	<b>8.47E+03</b>	<b>8.57E+03</b>

Öffnen von customer\_174\_3.txt

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Datei Bearbeiten Format Ansicht ?

X-RAYS AND GAMMA-RAYS:

Ancestor	Emitter	Energy, keV	X/G ray	Photons per decay	Emission rate, 1/s at start	Emission rate, 1/s at end	Photons emitted	Peak region counts peak area	Peak region counts peak bkgr	Detection efficiency total	Detection efficiency FEP	Filter att. factor	Ancestor's MDA(0), Bq
27 Co 60	27 Co 60	0.850	X	1.495E-006	1.494E-001	1.494E-001	1.494E+002	0.000E+000	7.332E+003	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	7.461	X	3.270E-005	3.269E+000	3.269E+000	3.269E+003	0.000E+000	1.071E+004	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	7.478	X	6.438E-005	6.435E+000	6.435E+000	6.435E+003	0.000E+000	1.071E+004	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	8.260	X	1.311E-005	1.310E+000	1.310E+000	1.310E+003	0.000E+000	9.207E+003	0.000E+000	0.000E+000	1.000E+000	NAN
27 Co 60	27 Co 60	347.140	G	7.500E-005	7.496E+000	7.496E+000	7.496E+003	1.856E+002	2.191E+004	6.240E-002	2.476E-002	1.000E+000	4.903E+005
27 Co 60	27 Co 60	826.100	G	7.600E-005	7.596E+000	7.596E+000	7.596E+003	6.568E+001	4.547E+004	4.902E-002	8.647E-003	1.000E+000	8.100E+006
27 Co 60	27 Co 60	1173.230	G	9.985E-001	9.980E+004	9.980E+004	9.980E+007	5.901E+005	1.625E+004	4.378E-002	5.914E-003	1.000E+000	6.865E-001
27 Co 60	27 Co 60	1332.490	G	9.998E-001	9.993E+004	9.993E+004	9.993E+007	5.145E+005	8.826E+001	4.195E-002	5.150E-003	1.000E+000	7.465E-001
27 Co 60	27 Co 60	2158.570	G	1.200E-005	1.199E+000	1.199E+000	1.199E+003	3.562E+000	1.378E-003	3.594E-002	2.971E-003	1.000E+000	1.079E+005
27 Co 60	27 Co 60	2505.690	G	2.000E-008	1.999E-003	1.999E-003	1.999E+000	0.000E+000	0.000E+000	3.448E-002	2.462E-003	1.000E+000	NAN
95 Am 241	95 Am 241	4.608	X	6.987E-002	3.492E+000	3.492E+000	3.492E+003	0.000E+000	1.375E+004	0.000E+000	0.000E+000	1.000E+000	NAN
95 Am 241	95 Am 241	14.440	X	3.307E-001	1.653E+001	1.653E+001	1.653E+004	1.329E+003	1.404E+004	9.476E-002	8.283E-002	1.000E+000	2.484E+001
95 Am 241	95 Am 241	97.080	X	1.286E-005	6.428E-004	6.428E-004	6.428E-001	5.458E-002	1.887E+004	9.093E-002	8.655E-002	1.000E+000	7.236E+000
95 Am 241	95 Am 241	101.070	X	2.068E-005	1.033E-003	1.033E-003	1.033E-003	8.651E-002	1.727E+004	9.033E-002	8.548E-002	1.000E+000	4.346E+005
95 Am 241	95 Am 241	113.310	X	2.399E-006	1.199E-004	1.199E-004	1.199E-004	1.199E-004	1.199E-004	1.199E-004	1.199E-004	1.000E+000	1.199E+004
95 Am 241	95 Am 241	114.240	X	4.570E-006	2.284E-004	2.284E-004	2.284E-004	2.284E-004	2.284E-004	2.284E-004	2.284E-004	1.000E+000	2.284E+004
95 Am 241	95 Am 241	117.500	X	2.564E-006	1.281E-004	1.281E-004	1.281E-004	1.281E-004	1.281E-004	1.281E-004	1.281E-004	1.000E+000	1.281E+004
95 Am 241	95 Am 241	13.810	G	1.656E-008	8.276E-007	8.276E-007	8.276E-007	8.276E-007	8.276E-007	8.276E-007	8.276E-007	1.000E+000	8.276E+007
95 Am 241	95 Am 241	26.345	G	2.430E-002	1.214E+000	1.214E+000	1.214E+003	1.214E+003	1.214E+003	1.214E+003	1.214E+003	1.000E+000	1.214E+003
95 Am 241	95 Am 241	27.040	G	6.264E-003	3.130E-001	3.130E-001	3.130E-001	3.130E-001	3.130E-001	3.130E-001	3.130E-001	1.000E+000	3.130E+001
95 Am 241	95 Am 241	28.510	G	2.772E-005	1.385E-003	1.385E-003	1.385E-003	1.385E-003	1.385E-003	1.385E-003	1.385E-003	1.000E+000	1.385E+003
95 Am 241	95 Am 241	31.400	G	6.120E-009	3.058E-007	3.058E-007	3.058E-004	2.860E-005	1.264E+004	9.703E-002	9.351E-002	1.000E+000	1.146E+011
95 Am 241	95 Am 241	33.196	G	1.217E-003	6.081E-002	6.081E-002	6.081E+001	5.708E+000	1.265E+004	9.701E-002	9.386E-002	1.000E+000	5.496E+003
95 Am 241	95 Am 241	38.570	G	1.260E-008	6.297E-007	6.297E-007	6.297E-004	5.960E-005	1.266E+004	9.691E-002	9.465E-002	1.000E+000	2.385E+010
95 Am 241	95 Am 241	40.500	G	6.120E-009	3.058E-007	3.058E-007	3.058E-004	2.897E-005	1.425E+004	9.685E-002	9.473E-002	1.000E+000	1.153E+011
95 Am 241	95 Am 241	42.720	G	3.852E-004	1.925E-002	1.925E-002	1.925E+001	1.820E+000	1.267E+004	9.676E-002	9.452E-002	1.000E+000	1.762E+004
95 Am 241	95 Am 241	43.420	G	6.588E-004	3.292E-002	3.292E-002	3.292E+001	3.110E+000	1.267E+004	9.673E-002	9.446E-002	1.000E+000	1.017E+004
95 Am 241	95 Am 241	51.010	G	5.400E-006	2.699E-004	2.699E-004	2.699E-002	2.544E-002	1.428E+004	9.632E-002	9.426E-002	1.000E+000	6.923E+006
95 Am 241	95 Am 241	54.080	G	2.664E-006	1.331E-004	1.331E-004	1.331E-001	1.253E-002	1.427E+004	9.610E-002	9.410E-002	1.000E+000	3.417E+006
95 Am 241	95 Am 241	55.550	G	1.836E-004	9.175E-003	9.175E-003	9.175E+000	8.627E-001	1.427E+004	9.600E-002	9.402E-002	1.000E+000	3.871E+004
95 Am 241	95 Am 241	56.880	G	2.340E-008	1.169E-006	1.169E-006	1.169E-003	1.098E-004	1.268E+004	9.590E-002	9.392E-002	1.000E+000	2.305E+014
95 Am 241	95 Am 241	59.541	G	3.600E-001	1.799E+001	1.799E+001	1.799E+004	1.685E+003	1.268E+004	9.566E-002	9.367E-002	1.000E+000	1.862E+001
95 Am 241	95 Am 241	64.820	G	5.760E-006	2.879E-004	2.879E-004	2.879E-001	2.680E-002	1.425E+004	9.517E-002	9.310E-002	1.000E+000	1.242E+006
95 Am 241	95 Am 241	67.450	G	2.160E-006	1.079E-004	1.079E-004	1.079E-001	1.001E-002	1.424E+004	9.490E-002	9.274E-002	1.000E+000	3.325E+006
95 Am 241	95 Am 241	69.760	G	2.880E-005	1.439E-003	1.439E-003	1.439E+000	1.331E-001	1.581E+004	9.466E-002	9.244E-002	1.000E+000	2.633E+005
95 Am 241	95 Am 241	75.920	G	5.760E-006	2.879E-004	2.879E-004	2.879E-001	2.631E-002	1.420E+004	9.392E-002	9.139E-002	1.000E+000	1.263E+006
95 Am 241	95 Am 241	78.100	G	2.088E-008	1.043E-006	1.043E-006	1.043E-003	9.498E-005	1.419E+004	9.366E-002	9.102E-002	1.000E+000	4.097E+008
95 Am 241	95 Am 241	92.200	G	6.120E-007	3.058E-005	3.058E-005	3.058E-002	2.687E-003	1.573E+004	9.167E-002	8.785E-002	1.000E+000	1.318E+007
95 Am 241	95 Am 241	96.800	G	1.368E-006	6.837E-005	6.837E-005	6.837E-002	5.922E-003	1.572E+004	9.098E-002	8.662E-002	1.000E+000	6.515E+006
95 Am 241	95 Am 241	98.970	G	2.232E-004	1.115E-002	1.115E-002	1.115E+001	9.601E-001	1.572E+004	9.066E-002	8.607E-002	1.000E+000	3.638E+004
95 Am 241	95 Am 241	102.960	G	2.088E-004	1.043E-002	1.043E-002	1.043E+001	8.858E-001	1.569E+004	9.001E-002	8.489E-002	1.000E+000	3.940E+004
95 Am 241	95 Am 241	109.700	G	1.224E-007	6.117E-006	6.117E-006	6.117E-003	5.071E-004	1.572E+004	8.892E-002	8.280E-002	1.000E+000	6.970E+007
95 Am 241	95 Am 241	115.500	G	8.280E-008	4.138E-006	4.138E-006	4.138E-003	3.351E-004	1.728E+004	8.794E-002	8.098E-002	1.000E+000	1.774E+008
95 Am 241	95 Am 241	120.400	G	4.680E-008	2.339E-006	2.339E-006	2.339E-003	1.854E-004	1.571E+004	8.710E-002	7.926E-002	1.000E+000	1.944E+008
95 Am 241	95 Am 241	123.000	G	1.080E-005	5.397E-004	5.397E-004	5.397E-001	4.231E-002	1.727E+004	8.667E-002	7.839E-002	1.000E+000	8.654E+005
95 Am 241	95 Am 241	125.310	G	4.104E-005	2.051E-003	2.051E-003	2.051E+000	1.592E-001	1.570E+004	8.630E-002	7.760E-002	1.000E+000	2.192E+005
95 Am 241	95 Am 241	129.000	G	7.200E-009	3.598E-007	3.598E-007	3.598E-004	2.742E-005	1.727E+004	8.563E-002	7.620E-002	1.000E+000	1.586E+009

Zeile 84, Spalte 1

Again find an <sup>241</sup>Am gamma-line with the lowest MDA value

Select "Open with Editor" and press OK

### Answer:

- The configurations with **LEGe** and **BEGe** detectors are suitable for detecting an additional presence of 50 Bq of  $^{241}\text{Am}$  in the  $^{60}\text{Co}$  source. The respective MDAs are 12,2 Bq and 18,6 Bq.

Thanks !

